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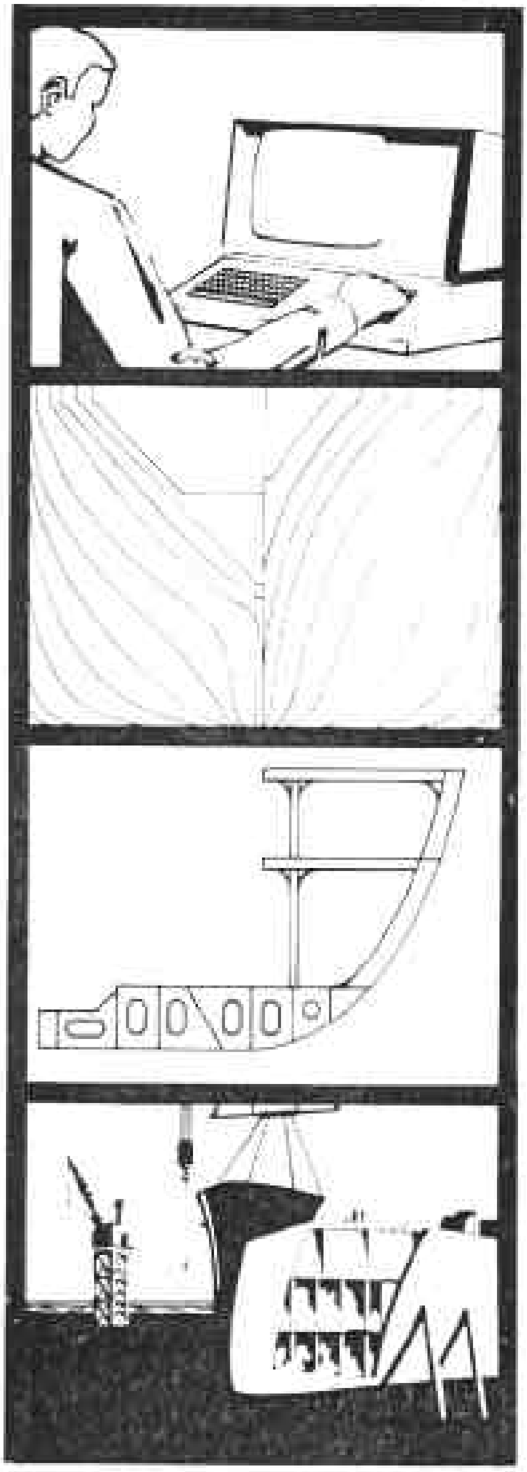

R ESEARCH
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HULSTRX - A CASDAC COMPUTER AID FOR HULL STRUCTURAL CONTRACT DESIGN

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The views expressed herein are the personal opinions of the author and are not necessarily the official views of the Department of Defense or any department thereof.

INTRODUCTION

This paper is a status report on the development of a computer aided design tool for representing and displaying ship structure. Program Hull Structure (HULSTRX) is being developed for the Navy's (NAVSEA) Surface Ship Structures Branch as a part of the Navy's Computer Aided Design and Construction (CASDAC) project. HULSTRX will aid the Navy primarily during the contract design phase of ship design, which is referred to as level III in the CASDAC project. However, it is expected that HULSTRX will also prove useful to structural designers during preliminary and detailed design studies.

Figure 1 shows how HULSTRX fits into the Navy's ship design process as a part of CASDAC's Hull Subsystem. Reference 1 describes the Hull Subsystem as a computer aid for developing:

a) the hull form,

b) the hull structure, and

c) the weight estimate for naval surface ships.

The Hull Subsystem is primarily intended for use during preliminary and contract design, although many of its elements will also be used during the earlier conceptual design phase. Its products and results serve as input to the Hull Detail Design and Construction Hull Subsystem (HULLDAC). The Hull Subsystem will interface with the Arrangement Subsystem via a Design Geometry Library (DGL).

Individual programs which are included in the Hull Subsystem and are also strongly linked to the structural design process and HULSTRX are:

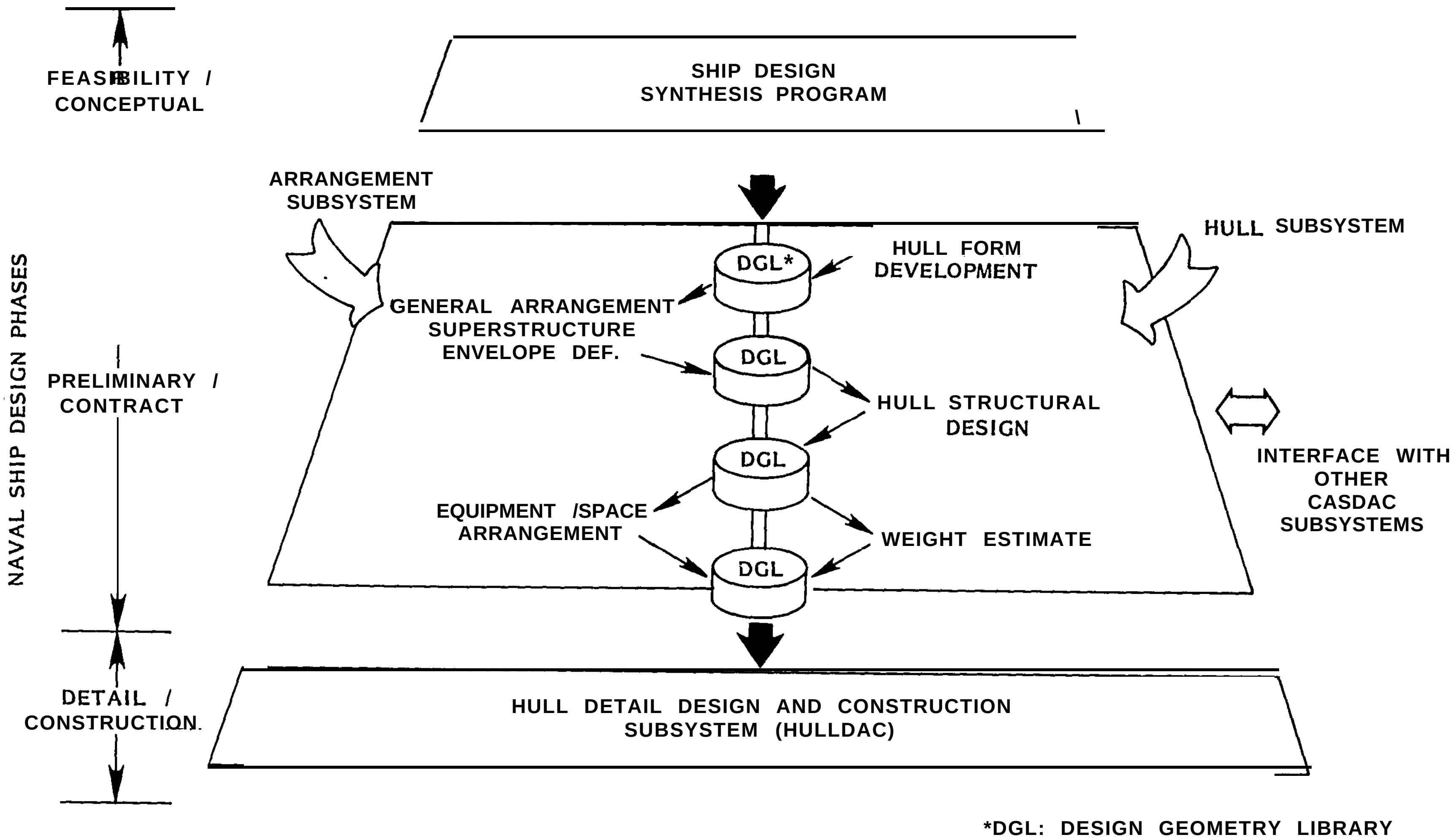

FIGURE 1 - CASDAC HULL SUBSYSTEM OVERVIEW AND SYSTEM INTERFACES

1. HULGEN, a ship hull form generator,
2. HULDEF, a ship hull definition program,
3. SHCP, a ship hull characteristics program,
4. SSDP, a structural synthesis design program, and
5. UPLOT, a general 2-D plotting program.

There are two main purposes of the Structures Branch for developing HULSTRX. The first purpose is to obtain a computer tool to use in generating their contract design deliverables. Design deliverables presently being addressed in HULSTEX are:

1. Drawings of midship section and typical sections,
2. Deck plans for all decks,
3. Expanded shell drawing, and
4. Deckhouse or superstructure drawings.

Other important HULSTRX outputs (not contract deliverables) will include:

1. Longitudinal strength study (this will involve a link to SHCP), and
2. Other structural calculations.

The above contract design deliverables, when produced by hand, necessitate tedious drafting and tabulating efforts. With the assistance of a computer tool, it is expected that there will be a reduction of consistency-type errors, and an increase in engineering effectiveness. Another very important by-product of the use of the computer will be availability of the structural design data in digital form for use in other design disciplines.

The second purpose of the Structures Branch for developing HULSTRX is to let the digital design data become a design deliverable. With HULSTRX, the design data base, and an interface routine, it will be possible to load design packages for detail design, thereby reducing manual data preparation time as well as consistency-type errors. It is hoped that HULSTRX will eventually become available to shipbuilders and others involved in detail design, in the same manner as HULDEF is being used.

The order of funding and development of aspects of HULSTRX are determined by the needs of the Structures Branch as well as the CASDAC office. In a paper presented at the June 1978 REAPS Technical Symposium, Tom Gallagher of the Structures Branch presented (Reference 2) his ideas on how a design agent can better assist shipbuilders. HULSTRX is the implementation of some of these ideas.

HULSTRX is being developed in a piece-wise fashion. There are also other studies occurring simultaneously which will strongly effect the development of HULSTRX. Specifically, the structure of the design geometry library (DGL) and the interface with the Arrangements Subsystem. Development of HULSTRX is proceeding with the understanding that changes will be made during development and use, a condition certainly not unique to HULSTRX. For example, there are plans to modify the Ship Hull Characteristics Program (SHCP), one of the most established programs in the Hull Subsystem. One of the important reasons for continual development of finished programs is that the programs themselves change the design process in unpredicted ways. This paper addresses the current status of HULSTRX with the understanding that changes are expected and desired.

HULSTRX DEVELOPMENT STATUS

HULSTRX is a modular program which will allow structural designers to develop and then use computerized files of structural arrangement data, such as stiffener and plate-edge traces, and structural member data, such as scantling and material information. The program will employ many of the concepts implemented in the HULDEF program. The three most important concepts borrowed from HULDEF are:

1. The program will initially be used in a batch mode.
2. The HULDEF file structure and format will be used *in* representing structural arrangement data.
3. HULDEF's parametric spline is being used to represent structural traces (3-D lines).

Many of HULDEF's routines that deal with the lines file and manipulate lines are being used in HULSTRX, and are described in References 3 and 4. Details of HULSTRX current development are presented below as inputs, structural trace processing (mapping methodology), and outputs to the program. Some of this material has been presented in Reference 5.

HULSTRX will accept design data from the structural designer in the following ways:

1. Design Geometry Library

The primary input to the structural design effort and to HULSTRX is the geometrical shape of the hull and the major hull subdivisions as represented by surface intersections. The DGL is (currently) first established by NAVSEA's Hull Form Branch, resulting in two surfaces, shell starboard snd shell port.

Major subdivision data will then be added to the DGL in the form of surface intersection lines. Surface intersection lines bounding a surface will be used to initiate the process of describing other surfaces, such as bulkheads, longitudinal bulkheads, and decks. The interface between the Hull and Arrangements Subsystems, the DGL, is currently under development, so the content and form of the DGL as input to HULSTRX is tentative. Figure 2 shows schematically the geometric hull shape and subdivision data that will be needed as input to HULSTRX.

2. Structural Design Data

HULSTRX will not directly deal with ship structural synthesis, but will represent and aid in the display of the structural design. The other major input to HULSTRX is the structural arrangement and scantling data generated by the structural designers.

The U.S. Navy uses a computer aided structural design tool called the Structural Synthesis Design program (SSDP) to develop longitudinal structure at a number of ship cross sections. SSDP, Reference 6, allows structural engineers to input the geometry of a particular transverse section consisting of major longitudinal surfaces such as shell, decks, platforms, and longitudinal bulkheads, along with loading conditions and longitudinal stiffener spacing (ranges). The program will design a section with the lowest practical weight, and will provide scantlings and structure that will comply with current U.S. Navy design criteria. Further development of SSDP is being considered to allow for design to American Bureau of Shipping standards.

During HULSTRX development, a digital interface will be developed between SSDP and HULSTRX. Data from the numerous section designs, consisting of plate thicknesses, stiffener scantlings (or stiffener size code), and stiffener spacing, will be passed to HULSTRX. This interface will relieve-designers from tedious data preparation tasks.

With the structural design data from SSDP available to HULSTRX, the designers will then immediately be able to display the design

SHIP, DATE

SHOOOS (SHELL STARBOARD)
CLOOO CENTERLINE
SHELL GEOMETRY LINES
BLANK(‘)

SURFACE NAME

TRACES IN END-POINT TANGENT FORM (HULDEF’S FORMAT)

SHOOOP (SHELL PORT)
SAME FORMAT AS FOR SHELL STARBOARD
BLANK

SURFACE NAME

TRACES IN END-POINT TANGENT FORM (HULDEF’S FORMAT)

DECK 1

DECK 2(2)

PLATFORMS

FLATS

TRANSVERSE BULKHEADS

LONGITUDINAL BULKHEADS

GIRDERS

NOTE :
(1) BLANK TRACE NAME INDICATES END OF SHELL SURFACE IN HULDEF
(2) EACH DECK, OR ANY OTHER CATEGORY OF SURFACE, MAY BE REPRESENTED AS A INDEPENDENT SURFACE SUB-FILE.

FIGURE 2 - DESIGN GEOMETRY LIBRARY DATA REQUIRED AS INPUT TO HULSTRX

and check for structural longitudinal continuity with structural body plan and shell expansion drawings.

3. Manually Generated Structural Design Data

Although most of the structural design data will be passed to HULSTRX via the SSDP interface, substantial changes and additions to the structural design will have to be made manually. For example, some of the longitudinal stiffeners formed by stringing the SSDP data together from the individual section designs must be dropped off at a specific point. Manually generated design data will be input using numerous concise formats. Examples of the ways geometric data for structural traces will be submitted include:

1. Single lines as defined by numerous coordinate pairs (the program will calculate the third coordinate forming a triplet),
2. Longitudinal equally spaced lines,
3. Reflected (mirror image) lines.

Development of HULSTRX to this point has included establishing how the structural arrangement data from the SSDP will be accurately mapped onto the various ship surfaces. This mapping process will be described for the shell surface.

SSDP specifies how stiffeners are positioned on a segment of the shell surface, at a particular ship cross section, by simply defining the stiffener spacing within that shell segment. Shell segments are defined by the user. For one stiffener, the girth at that section can be calculated, and With the section's longitudinal position expressed as an x-value, a point on the stiffener is uniquely defined as (girth,x), and can easily be converted to a coordinate triple. Other points defining the position of this stiffener *are* obtained from SSDP output at different sections. If these points are then splined forming a longitudinal stiffener trace, points on the trace between definition points may not fall on the ship's molded surface. The method developed for mapping a trace onto the shell surface employes many of the procedures and routines in the HULDEF program. Before describing the procedure, it is necessary to describe the means for defining the shell geometry.

Shell surface geometry is defined primarily by longitudinal girth-fraction lines. A girth-fraction line is a longitudinal line formed by splining points on sections, where the point on each section is located at a fraction of the girth on that section. Alternatively, the shell surface geometry can be defined with other types of longitudinal lines, such as waterlines.

The hull designer uses HULDEF to fair a family of longitudinal lines. These longitudinal shell definition lines generally consist of about nine girth-fraction lines, *a* deck-at-edge line; stem line, transom line, and other lines that help specify knuckles or flat plate areas in the hull. For the purposes of this discussion, these lines will be referred to as the longitudinal shell definition lines, or L-lines.

Various options in HULDEF allow the hull designer to create section, waterline, buttock, and diagonal lines on the shell surface. Sections are created by intersecting the L-lines with an x-plane: find all L-line intersections with an x-plane, and spline the intersection points. These transverse cuts, stations or frames, can then be plotted and/or stored on the DGL, in the shell surface. The number of stations or frames stored on the DGL is user-dependent. These stations or frames will be referred to as the transverse shell lines, or T-lines. The hull designer usually specifies enough stations for a plot so that a visual check of the lines fairness can be made.

'When other longitudinal lines, such as waterlines and buttocks are to be generated (for plotting or storing), HULDEF first creates a temporary file of T-lines. The number of transverse cuts of the L-lines made to create this temporary file of T-lines is user-dependent. A T-line is made at every station or frame specified by the user, but when stations are specified (as opposed to frames), this list is automatically supplemented by the program to include T-lines at l/4, l/2, and 3/4 station spacing. Once this temporary T-line file is created, waterlines, buttocks, and diagonals (all considered longitudinal lines) can be created in a manner similar to that of transverse lines. The temporary file of T-lines is cut by the appropriate plane forming the points of intersection. Some of the L-lines, control lines and form lines, are also cut by this plane and are added to the list of T-line intersections. All of the intersections are then splined and the line is plotted and/or filed into the DGL shell surface.

When a transverse line of the shell surface is needed, the longitudinal shell geometry lines (L-lines) are cut. When a longitudinal line is needed, a temporary transverse lines file is first created by cutting the L-lines, and then the T-lines are cut to form the new longitudinal line.

Together, the L-lines and the temporary T-lines form a grid of lines over the shell surface which completely defines the shape of the shell surface. The only information needed to generate this grid is the original L-lines, and a list of x-values of station or frame positions. This information, together with the parametric spline and line-cutting algorithms, provides for a concise and accurate means of representing the shell surface.

Structural traces to be mapped onto the hull surface will be considered as one of two types:

- Straight traces - lines that are straight when viewed in at least' one of the three Primary planes (x-plane, y-plane,. or z-plane). The program will recognize structural traces as being straight when the input for the trace consists of exactly two coordinate pairs: two (X,Y) pairs, two' (x,z) pairs, or two (x, girth) pairs.
- Curved traces - lines that are defined by more than two coordinate pairs.

A straight or curved trace to be mapped onto the shell surface will either be -considered a longitudinal trace or a transverse trace according to the following-rules!'

- For (x,y) input pairs, if $\left|\frac{\Delta x}{\Delta y}\right| \leq 0.5$, line is transverse

  if $\left|\frac{\Delta x}{\Delta y}\right| > 0.5$, line is longitudinal

- For (x,z) input pairs, if $\left|\frac{\Delta x}{\Delta z}\right| \leq 0.5$, line is transverse

  if $\left|\frac{\Delta x}{\Delta z}\right| > 0.5$, line is longitudinal

The mapping routine will be initiated by creating a temporary file of T-lines as previously described. The x-positions for the transverse cut of the L-lines will be determined by reading the positions of the stations or frames already on the DGL shell surface. If station lines' are on the shell surface, as opposed to frames, the x-value list will be supplemented with the l/4, l/2, and 3/4 station x-values,

Once the temporary file (stored on secondary, disk, memory) is established,. each structural trace is mapped onto the shell surface, one line at a time. If an error is encountered during the processing, an error message is written via the line printer and processing for the next trace started.

If a straight line is transverse, all the L-lines will be cut, forming point intersections. These points will then be splined, and the splined line will be "snipped" off at its endpoints.

If the straight line is longitudinal, the T-lines will be cut by a plane. Five T-lines forward and aft of the line endpoints will be cut, if available, assuring that the line is precisely mapped onto the shell surface. The resulting splined line will then be snipped to the appropriate length, and stored.

For curved lines, the mapping procedure is quite different. If the curved (input) structural trace is transverse, a longitudinal cut of the T-lines will be needed, using either a y or z plane, to form a temporary longitudinal line, a major line. The new major line will be intersected with the input line to produce an intersection containing the third coordinate of the input point. A temporary longitudinal line will be required for each input point in the trace.

The next step for a curved, transverse line will be to find the coordinate triples of any of the original L-lines within the endpoints of the trace. Coordinate triples (approximately four) will also be required beyond the endpoints of the trace to insure that the ends of the trace are precisely mapped onto the shell surface. When all of the triples are found, the line will be splined, snipped off at the trace endpoints, and filed in the DGL.

Curved traces that run in the longitudinal direction are processed in a similar manner. The major difference is that the temporary major lines needed to intersect the trace at each input point are derived by cuts of the L-lines.

The primary outputs from HULSTRX are the following computer drawings of the design deliverables:

1. Midship section and typical sections,
2. Deck plans for all decks,
3. Expanded shell drawing, and
4. Deckhouse or superstructure.

These drawings will be made by specialized routines in some cases, or by employing the UPLOT program. In the course. of gathering the structural design data for the drawings,' the design geometry library will receive selected structural data and two new files will be created, a structural arrangement file, containing all structural traces to the level of detail corresponding to current contract design, and a structural scantlings file which will contain the scantlings of the steel shapes used in naval shipbuilding, as described in Reference 7.

The drawings will be made by referencing geometric data in the DGL and structural arrangement and scantling data in the other two files. Any further details will be obtained from computerized representations of the U.S. Navy standard structural details now under development, Reference 8.

Another important HULSTRX output will include a printed gross structural bill of material listing the structural elements and their quantities, in length or area units, by size of the members contained in the entire ship and/or for the individual surfaces.

It is hoped that the digital design data base, formed as a by-product of the contract design, will itself become a contract design deliverable, making it easier for those concerned with detail design to produce new or revised drawings. or to load detail design programs.

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